Multiple Flow Processes Accompanying a Dam-break Flood in a Small Upland Watershed, Centralia, Washington

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Abstract

On October 5, 1991, following 35 consecutive days of dry weather, a 105-meter long, 37-meter wide, 5.2-meter deep concrete-lined water-supply reservoir on a hillside in the eastern edge of Centralia, Washington, suddenly failed, sending 13,250 cubic meters of water rushing down a small, steep tributary channel into the city. Two houses were destroyed, several others damaged, mud and debris were deposited in streets, on lawns, and in basements over four city blocks, and 400 people were evacuated. The cause of failure is believed to have been a sliding failure along a weak seam or joint in the siltstone bedrock beneath the reservoir, possibly triggered by increased seepage into the rock foundation through continued deterioration of concrete panel seams, and a slight rise (0.6 meters) in the pool elevation. A second adjacent reservoir containing 18,900 cubic meters of water also drained, but far more slowly, when a 41-cm diameter connecting pipe was broken by the landslide. The maximum discharge resulting from the dam-failure was about 71 cubic meters per second. A reconstructed hydrograph based on the known reservoir volume and calculated peak discharge indicates the flood duration was about 6.2 minutes. Sedimentologic evidence, high-water mark distribution, and landforms preserved in the valley floor indicate that the dam failure flood consisted of two flow phases: an initial debris flow that deposited coarse bouldery sediment along the slope-area reach as it lost volume, followed soon after by a water-flood that achieved a stage about one-half meter higher than the debris flow. The Centralia dam failure is one of three constructed dams destroyed by rapid foundation failure that defines the upper limits of an envelope curve of peak flood discharge as a function of potential energy for failed constructed dams worldwide.

INTRODUCTION

Centralia, Washington is located in the southern end of the Puget Trough about 135 km south of Seattle (fig. 1). At about 10:15 AM on October 5, 1991 the hillslope under the southwestern side of a concrete-lined water-supply reservoir used by the city of Centralia located on Seminary Hill (NE 1/4 SW 1/4, sec 9, T14N, R2W) suddenly failed. A roily mass of water, vegetation, and sediment flowed down a small, steep tributary into the eastern part of the city, destroying two houses, flooding scores more, and forcing the evacuation of 400 people. The dam failure occurred on a clear sunny morning after a prolonged period of dry weather. Temperatures were well-above normal in August and September, and no measurable rainfall had occurred for 35 days prior to the failure (NOAA, 1991).

The reservoir that failed was named "Reservoir Number 3." This reservoir is 105 m long, 37 m wide, 5.2 m deep, contained 13,250 m^3 of water, and was constructed in 1914. It was one of two adjacent reservoirs constructed of unreinforced concrete panels to store water from well fields for the water supply of the City of Centralia. The second reservoir ("Reservoir Number 4"), is 121 m long, 39 m wide, 6.1 m deep,

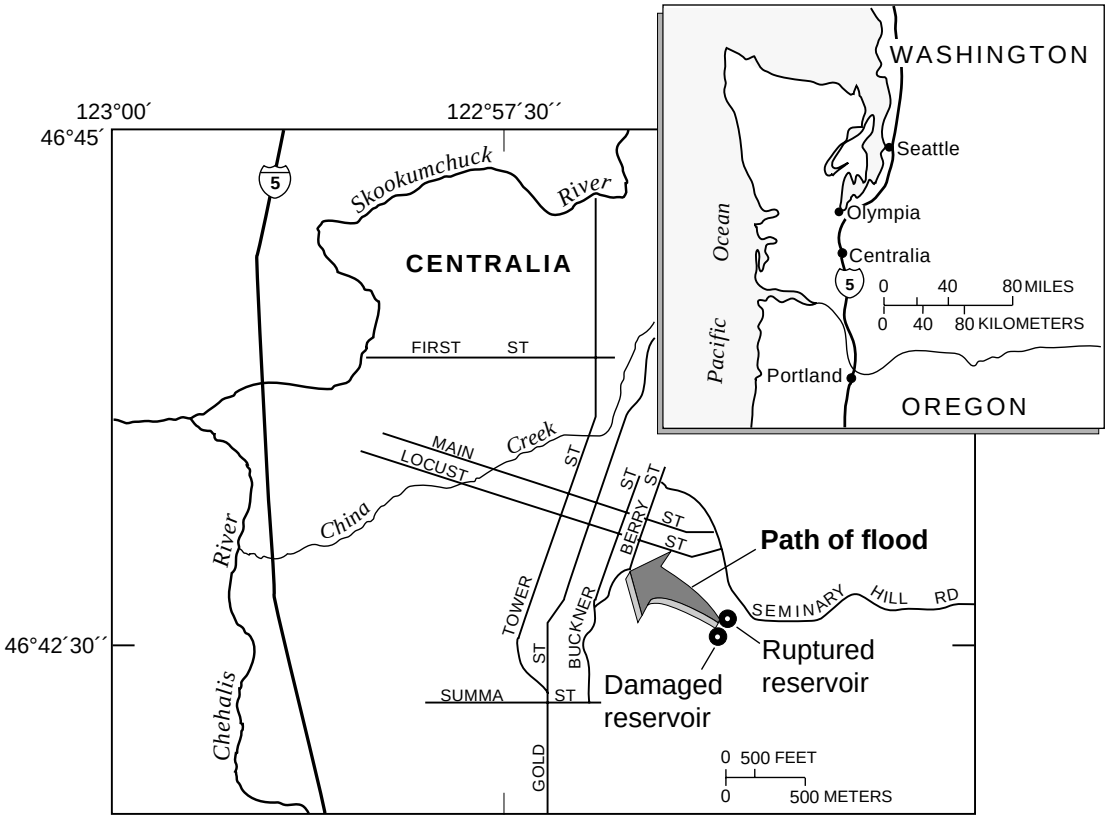

Figure 1. Location map of Centralia, Wash. and water-supply reservoirs that failed on Oct. 5, 1991.

stored 18,900 m^3 of water and was constructed in 1926. Both reservoirs have 1:1 interior sideslopes (fig. 2). The reservoirs were excavated into bedrock below original ground level, and some of the excavated material was used as fill on the west side of the hillslope. The embankment failure under Reservoir Number 3 caused the service and drain pipes connected to the larger second reservoir (Reservoir Number 4) to break, allowing uncontrolled release of an additional 18,900 cubic meters of water through a 41-centimeter-diameter pipe over the next several hours.

Purpose and Scope

This report presents documentation of the failure mechanism, peak discharge, geomorphology, and sedimentology of the failure of a constructed dam in a small upland watershed. Such floods are poorly documented compared with rainfall-runoff or snowmelt floods, and present unique hazards because dam failures and resultant flash flooding can occur at any time without warning, even during sunny weather.

Acknowledgements

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DAM-FAILURE CIRCUMSTANCES

The cause of this failure is not known with certainty, but increased seepage into the fractured bedrock foundation through continued deterioration of the concrete panel seams must have been a significant factor. Post-failure inspection of the seams between the concrete panels indicated that at least two kinds of caulking had been used in attempts to seal the gaps in the past. Maintenance and repair records for these reservoirs document they have had a history of excessive leakage for at least the last 33 years. In 1971 leakage rates were measured in Reservoir Number 3 when it was only 80 percent full. Over four percent of the capacity of the reservoir (545 cubic meters) was being